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# TRIPOD CONSTANT VELOCITY UNIVERSAL JOINT

## BACKGROUND OF THE INVENTION

### a. Field of Invention

The present invention relates to a plunging type tripod constant velocity universal joint for use in transmission of power in automobiles, industrial machines, and the like.

### b. Prior Art

Sub a2> A tripod constant velocity universal joint, as shown in the left half of Fig. 4, comprises an outer joint member 10' having three axial track grooves 12' in the inner periphery thereof and formed with roller guide surfaces 14' in the opposed side walls of each track groove 12', a tripod member 20' having a trunnion barrel 21 adapted to be fitted to a shaft for torque transmission and trunnion journals 22' radially projecting from three circumferentially equispaced positions on the trunnion barrel 21', and rollers 30' each rotatable around the trunnion journal 22' through a plurality of needle rollers 32' and received in the track grooves 12' of the outer joint member 10', the roller 30' being guided in the outer peripheral surface by the roller guide surfaces 14'.

There are two forms of contact between the roller 30' and the roller guide surfaces 14'; angular contact and circular contact. Angular contact has a certain contact angle and occurs at two points (Fig. 5A). Circular contact occurs at one point and the contact ratio generally employed ranges from 1.002 to 1.008 (Fig. 5B).

Sub A3> In the case of angular contact, when a contact ellipse is produced at two points in the direction of the contact angle and a predetermined torque is applied, it is necessary that the contact ellipse be in the width of the roller 30'. For this reason, in the existing circumstance, the proportion of the width of the roller 30' to the outer diameter ranges from 32% to 36%. Further, even if the contact angle and contact ratio are reconsidered, the total widthwise contact length exceeds the width of the roller 30'. The phenomenon of both ends of the roller 30' cutting into the roller guide surfaces 14' or the phenomenon of two contact ellipses overlapping each other in the middle of the roller 30', which has been an obstacle to improvement of life and to the reduction of vibration, cannot be avoided.

Sub A4> In the case of conventional circular contact, since the contact ratio ranges from 1.002 to 1.008 when a predetermined torque is applied, the widthwise contact

ellipse length some times exceeds the width of the roller 30'. For this reason, there is a limit to the reduction of the width of the roller 30' as in the case of angular contact. In the existing circumstances, the proportion of the width of the roller 30' to the outer diameter ranges from 32% to 36%. Further, if the width of the roller 30' is reduced, the total widthwise contact length far exceeds the width of the roller 30', obstructing the improvement of life and the reduction of vibration.

Sub A5> Further, in both angular contact and circular contact, the roller guide surfaces 14' have a radius of curvature at a certain contact ratio and the major and minor inner diameters are, as such, connected at R (without relief). When the tripod joint is rotating while taking an operating angle, an angular displacement also occurs between the roller 30' and the roller guide surfaces 14'. This causes wearing of the roller guide surfaces to proceed. Then, there occurs on both the major and minor diameter sides the phenomenon of both ends of the roller 30' cutting into the roller guide surfaces 14', forming a cause of increasing the vibration.

Accordingly, an object of the invention is to solve the problems as described, so as to achieve reduced vibration and hence weight reduction and compactification

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Sub A6> It has been found that the NVH characteristic of tripod joints depends on the angle at which needle rollers can actually skew. The skew angle is determined by the radial clearance and circumferential clearance but this has not heretofore been taken into consideration. Therefore, the NVH characteristic differs according to differences in the proportions or size of a tripod joint and optimization of this situation has not been made at present.

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Generally, tripod joints are designed with particular attention paid to the aspect of strength (torsional

strength). The strength is uniquely determined usually by the minimum outer diameter of the shaft, and then the strength of the tripod member or the strength of the roller is considered. The strength is evaluated mainly in two ways: static torsional strength (test), and pulsating fatigue strength (test). Usually, in the two tests, it is arranged that the shaft is the first to break. Therefore, it is arranged that the tripod member or the roller has a strength not less than that of the shaft.

The static torsional strength is evaluated, in a static torsional test with torque applied to a tripod joint, by a torque with which one region or another is torsionally broken. The pulsating fatigue strength is evaluated by the number of cycles with which one region or another breaks when a predetermined pulsating torque is applied to a tripod joint.

The strength of the tripod member depends on the strength of the root of the trunnion journal and the strength of the trunnion barrel. Increasing the trunnion journal diameter increases the strength of the root of the trunnion journal, and increasing the outer diameter of the trunnion barrel increases the strength of the trunnion barrel.

However, increasing the trunnion journal diameter would necessarily increase the outer diameter of the roller, while increasing the outer diameter of the trunnion barrel would involve an increase in the minor inner diameter of the outer joint member. Therefore, in achieving the weight reduction and compactification of the tripod joint, it is not sufficient simply to reduce the size of the shell of the outer joint member, since limitation is imposed on the operating region (geometry) of the tripod joint; therefore, balanced design of the various portions becomes important.

Further, rolling fatigue life (flaking life) of the rolling section, particularly between the needle rollers and the trunnion journal also has to be considered. In durability tests, when the tripod joint is driven at a predetermined rpm while applying a predetermined torque, the evaluation of durability is made by the number of cycles or time taken for flaking to occur. Usually, this durability can be improved by increasing the outer diameter or length of needle rollers or their number, as is known; however, this would lead to an increase in the size of the shell of the outer joint member.

Therefore, with the balance between strength and durability in mind, the present invention is also intended to reduce the size of the shell of the outer joint member

as much as possible so as to achieve weight reduction and compactification of a tripod joint.

#### SUMMARY OF THE INVENTION

Sub A7> According to an embodiment of the invention, a tripod type constant velocity universal joint comprises an outer joint member having three axial track grooves in the inner periphery and roller guide surfaces formed in the opposed side walls of each track groove, a tripod member having three radially projecting trunnion journals, and rollers rotatable around the respective trunnion journals through a plurality of needle rollers and received in the track grooves of the outer joint member, each roller being guided in the outer peripheral surface by the roller guide surfaces, wherein contact between the roller and the roller guide surfaces is circular contact whose contact ratio is 1.01 or above and the width dimension of the roller is reduced to the extent that the contact ellipse produced in the roller during the application of a predetermined torque does not deviate from the end surface of the roller. By ensuring that the form of contact between the roller and the roller guide surfaces is circular contact and setting the contact ratio such that the widthwise contact ellipse length under a predetermined torque load is not more than the widthwise length of the roller, it is made possible to

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achieve weight reduction, compactification and good durability.

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Sub A8> The contact ratio of the roller to the roller guide surface may be so set that the surface contact pressure produced on the roller during the application of a predetermined torque is not more than the contact surface pressure produced between the trunnion journal and the needle rollers. In particular, the contact ratio of the roller to the roller guide surface may range from 1.02 to 1.2.

The ratio  $L_s/d_o$  of the width ( $L_s$ ) to the outer diameter ( $d_o$ ) of the roller may be equal to or less than 0.32. Preferably, the ratio  $L_s/d_o$  may range from 0.24 to 0.27. As the result of setting the contact ratio so that the contact ellipse length is equal to or less than the widthwise length of the roller, it becomes possible to reduce the roller width, contributing to the compactification of the outer joint member and hence of the tripod joint.

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Sub A9> The portion of the roller guide surface corresponding to the end of the roller may be formed with a relief portion. The provision of such relief portion prevents the roller from cutting into the roller guide surfaces and

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makes it possible to obtain good vibration characteristics. Since the corner R portion (which is a cold forged surface, thus having no edge) which connects the radius of curvature, R, of the roller guide surfaces to the relief portion makes contact within the range of the roller outer diameter R surface, no cutting-in occurs. Preferably, the relief portion may be in the form of an arc smoothly connected to the roller guide surface.

The angle at which a needle roller can actually skew, that is, the freedom of making of skew angle is restricted by the diametrical clearance (radial clearance) and by the clearance between rollers in the pitch circle (circumferential clearance), and the smaller of the two clearances has a greater influence. In the case of skew due to circumferential clearance, skewing is allowed until needle rollers contact each other; thus, the skew angle ( $\theta_1$ ) in this case is expressed by formula 1:

$$\theta_1 = \cos^{-1} \{ d / (D - d) \} \sin(\pi / Z) \quad (1)$$

In formula 1, D is the inner diameter of the rollers, d is the needle roller diameter and Z is the number of rollers.

Further, in the case of skewing based on the radial clearance, since skewing can continue until both ends of the roller contact the roller inner diameter, the skew

angle  $\theta 2$  this time is expressed by formula 2:

$$\theta 2 \doteq \sin^{-1}(2\sqrt{Dgr}/l) \quad (2)$$

In formula 2, gr is the radial clearance and l is the effective length of the roller.

<Sub 410> These skew angles  $\theta 1$  and  $\theta 2$  are obtained and the smaller one is the skew angle that can actually occur (refer to "BEARINGS" BY Norimune Soda, published by Iwanami Shoten, Publishers).

And when the radial clearance is set so that the relation between both skew angles  $\theta 1$  and  $\theta 2$  is  $\theta 1 > \theta 2$  and so that the skew angle  $\theta 2$  is  $4.0^\circ - 4.5^\circ$ , it has been found that the vibration producing force on the tripod joint is at a minimum. With this taken into consideration, it is possible to attain optimization concerning the reduction of vibration of the tripod joint.

According to another embodiment of the invention, the tripod constant velocity universal joint comprises an outer joint member having axially extending track grooves formed at three circumferentially equispaced positions in the inner periphery, a tripod member consisting of a trunnion barrel adapted to be fitted to a shaft for torque

transmission and trunnion journals radially projecting from three circumferentially equispaced positions in the trunnion barrel, and rollers respectively attached to the trunnion journals for rotation through a plurality of needle rollers and received in the track grooves, each roller being guided at its outer peripheral surface by roller guide surfaces formed in opposite lateral walls of the track groove, wherein the skew angle of the needle rollers is controlled so that it is within a predetermined specified value.

The skew angle ( $\theta_2$ ) of the needle rollers which is caused by the radial clearances in the needle rollers in an annular space between the roller and the trunnion journal may be controlled so that it is within a predetermined specified value. The skew angle ( $\theta_2$ ) can be determined by suitably combining the values of the roller inner diameter  $D$ , radial clearance  $gr$ , effective length  $l$  of the needle roller, on the basis of formula 2 as previously referred to.

Specifically, the preferable range of skew angle ( $\theta_2$ ) may range from  $4.0^\circ$  to  $4.5^\circ$ . This is based on the finding that the thrust force is at a minimum when the skew angle ( $\theta_2$ ) is in the range of  $4.0^\circ - 4.5^\circ$ . If the skew angle ( $\theta_2$ ) exceeds  $4.5^\circ$ , the thrust force increases, until it is saturated at a certain level, while, reversely

if the skew angle ( $\theta 2$ ) is less than 4.0, the thrust force tends to increase.

The skew angle ( $\theta 1$ ) of the needle rollers which can be produced by the circumferential clearances may be larger than the skew angle ( $\theta 2$ ) of the needle rollers which can be produced by the radial clearances in an annular space between the roller and the trunnion journal. As described above, the smaller of the two types of skew angles, the skew angle ( $\theta 1$ ) which can occur due to the circumferential clearance and the skew angle ( $\theta 2$ ) which can occur due to the radial clearance, is the skew angle which can actually occur; therefore, measures against skewing of needle rollers can be taken by controlling only this skew angle ( $\theta 2$ ) by reducing the latter.

The contact ratio between the roller and the roller guide surfaces may range from 1.02 to 1.2 and the width dimension of the roller may be reduced to such a degree that the contact ellipse produced in the roller does not deviate from the end surface of the roller during the application of a predetermined torque. The reason is that if the contact ratio is small during the torque application, the contact ellipse becomes larger, exceeding the width dimension of the roller, leading to a short life, while, reversely, if the contact ratio is large, the contact

ellipse becomes smaller, but the surface pressure increases, accelerating the wearing of contact portions, leading to a short life.

Further, reducing the width dimension of the roller contributes to the compactification of the outer joint member and hence the tripod joint in its entirety. Specifically, it may be preferable that the ratio ( $L_s/d_o$ ) of the width ( $L_s$ ) to the outer diameter ( $d_o$ ) of the roller be in the range of 0.24 - 0.27. The smaller this ratio ( $L_s/d_o$ ), the smaller the width ( $L_s$ ) of the roller for its outer diameter ( $d_o$ ), contributing more greatly to the compactification. However, excessively reducing the ratio would increase the surface pressure, leading to lowering the strength and durability; thus, the lower limit has been determined from this point of view.

The width dimension of the rollers and the length of the needle rollers may be so set that the contact surface pressure produced between the roller and the roller guide surfaces is substantially equal to the contact surface pressure produced between the trunnion journal and the needle rollers. The reason is that equalizing the contract pressures prevents premature wearing of either one to ensure that the durability of the tripod joint in its entirety will not be degraded.

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- [illegible]

- ③ Minor inner diameter/major inner diameter of outer joint member ( $\phi D2/\phi D1$ )
- ④ Roller width/roller outer diameter ( $Ls/\phi Ds$ )
- ⑤ Trunnion journal diameter/roller outer diameter ( $\phi Dj/\phi Ds$ )
- ⑥ Trunnion journal diameter/shaft diameter ( $\phi Dj/\phi ds$ )
- ⑦ Needle roller length/trunnion journal diameter ( $Ln/\phi Dj$ ).

Reconsideration of the dimensional proportions in the seven above-mentioned items provides an arrangement for tripod joints which is balanced between strength and durability and which is light in weight and compact. Further, it becomes possible to secure the slide amount without decreasing the operating region (geometry). And the reduction of the difference in wall thickness between the major and minor inner diameters of the outer joint member, and the reduction of the trunnion journal length make it possible to improve forgeability.

According to other embodiment of the invention, the tripod joint comprises an outer joint member having axially extending track grooves formed at three circumferentially equispaced positions in the inner periphery, a tripod member consisting of a trunnion barrel adapted to be fitted to a shaft for torque transmission and trunnion journals



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The ratio  $d_s/PCD$  of the diameter  $d_s$  of the shaft to the pitch circle diameter  $PCD$  of the roller guide surfaces may range from 0.50 to 0.55.

The ratio  $D_2/D_1$  of the minor inner diameter  $D_2$  to the major inner diameter  $D_1$  of the outer joint member may range from 0.66 to 0.72.

The ratio  $L_s/D_s$  of the width  $L_s$  to the outer diameter

DS of the rollers may range from 0.24 to 0.27.

The ratio  $(L_n/D_j)$  of the length  $L_n$  of the needle rollers to the trunnion journal diameter  $D_j$  may range from 0.47 to 0.50.

The ratio  $D_j/D_s$  of the trunnion journal diameter  $D_j$  to the roller outer diameter  $D_s$  may range from 0.54 to 0.57.

The the ratio  $D_j/d$  of the trunnion journal diameter  $D_j$  to the diameter  $d$  of the shaft may range from 0.83 to 0.86.

Sub A1) The roots of the the trunnion barrel and the trunnion journal may be of two-step shape, and the corner at the trunnion journal may be one R surface, or a round surface, continuously extending with a predetermined radius of curvature.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an enlarged sectional view of a region of contact between a roller and a roller guide surface in a tripod constant velocity universal joint according an embodiment of the invention;

Fig. 2A is a cross sectional view of the tripod joint;

1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430
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Fig. 4 shows cross sectional views of tripod joints, with an embodiment of the invention and a conventional example shown side by side for comparison;

Fig. 5A and 5B are enlarged sectional views of a region of contact between the roller and the roller guide surface, respectively showing angular contact and circular contact;

Fig. 7 is a graph showing the relation between skew angle ( $\theta_2$ ) and induced thrust;

Fig. 8B is an enlarged sectional view of a portion corresponding to Fig. 8A in a conventional tripod joint;

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## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figs. 1 through 3C, a first embodiment of the present invention will be described.

As shown in Figs. 2A and 2B, a tripod constant velocity universal joint has, as main components, an outer joint member 10 which connects to one of two rotary shafts to be connected, and a tripod unit (20, 30, 32) which connects to the other rotary shaft.

The outer joint member 10 is in the form of a hollow cup having three axially extending circumferentially equispaced track grooves 12. Each track groove 12 has roller guide surfaces 14 formed in the opposed side walls thereof. This roller guide surface 14 is part of a cylindrical surface, i.e., a partial cylindrical surface, parallel with the axis of the outer joint member 10. The cross section of the outer joint member 10 is, as shown in Fig. 3A, in the form of a corolla in which circumferentially alternately appearing minor inner diameter portions 16 of diameter D1 and major inner diameter portions 18 of diameter D2 are connected by the roller guide surfaces 14.

The tripod unit includes a tripod member 20, roller

30 and a plurality of needle rollers 32.

The tripod member 20 has three radially projecting trunnion journals 22 at circumferentially equispaced positions. As shown in Fig. 3B, each trunnion journal 22 has a cylindrical outer peripheral 24 and an annular ring groove 26 formed adjacent the shaft end. The trunnion journal 22 has a roller 30 rotatably fitted thereon through a plurality of needle rollers 32. The cylindrical outer peripheral surface 24 of the trunnion journal 22 provides an inner raceway surface for the needle rollers 32. The inner peripheral surface of the roller 30 is cylindrical and provides an outer raceway surface for the needle rollers 32.

The needle rollers 32 contact an outer washer 34 at their end surfaces disposed outside as seen radially of the trunnion 20 and an inner washer 38 at their opposite end surfaces. Axial movement of the outer washer 34 is controlled by a circlip 36 fitted in the ring groove 26 and hence the axial movement of the needle rollers 32 is also controlled. As shown in Fig. 3C, the outer washer 34 consists of a disk portion 34a extending radially of the trunnion journal 22, and a cylindrical portion 34b extending axially of the trunnion journal 22. The cylindrical portion 34a of the outer washer 34 has an outer

diameter smaller than the inner diameter of the roller 30 and its end 34c disposed outside as seen radially of the tripod member 20 is increased in diameter to have a diameter larger than the inner diameter of the roller 30. Therefore, the roller 30 is capable of moving axially of the trunnion journal 22.

Sub B. The outer peripheral surface of the roller 30 is part of a spherical surface, i.e., a partial spherical surface, and has a center of curvature at a portion radially spaced away from the axis and its curvature is slightly smaller than that of the roller guide surfaces 14 (see Fig. 1). Further, the form of contact between the roller 30 and the roller guide surfaces 14 is arc-to-arc contact as seen in a cross section, i.e., circular contact.

If the contact ratio of the roller 30 to the roller guide surfaces 14 is smaller, during the application of torque the contact ellipse becomes larger, until it exceeds the width of the roller 30, thus reducing the life. Reversely, if the contact ratio is larger, the contact ellipse becomes smaller, but the surface pressure increases to accelerate the wearing of the contact portions, thus reducing the life. Structurally, however, the surface pressure in the tripod joint is severest in the region between the trunnion journal 22 and the needle rollers 32;

therefore, it is recommended to set the contact ratio so that the surface pressure in this region does not exceed the limit. Specifically, this contact ratio is preferably in the range of 1.02 - 1.2, more preferably 1.05 - 1.18.

By setting the contact ratio so that the length of the contact ellipse is not more than the widthwise length  $L_s$  (Fig. 3B) of the roller 30, it becomes possible to reduce the width of the roller 30. Further, doing so contributes to the compactification of the outer joint member 10 and hence the tripod joint in its entirety. Concretely, the ratio  $L_s/d_o$  of the width  $L_s$  to the outer diameter  $d_o$  of the roller 30 is 0.32 or less, more preferably 0.24 - 0.27. The contact ellipse is shown in two-dot chain lines in Fig. 1.

As the tripod joint rotates while taking an operating angle, an angular displacement also occurs between the roller 30 and the roller guide surfaces 14. At this time, as already described, there occurs a phenomenon in which both ends of the roller 30 cut into both ends of the roller guide surfaces 14, i.e., the minor and major inner diameter portions 16 and 18 of the outer joint member 10, with the result that the vibration characteristics aggravates. To prevent this, as shown in Fig. 1, relief portions 15a and 15b are formed in both ends of the roller guide surfaces 14.

Let  $d$  be the diameter of the relief portions 15a and 15b and  $d_i$  be the diameter of the end surface of the roller 30, then the amount of relief is expressed by  $(d - d_i) / 2$ . If this amount of relief is too small, the phenomenon of the roller 30 cutting into the roller guide surfaces 14 cannot be effectively avoided. Reversely, if the amount of relief is too large, the roller 30 slips off or the area of contact between the roller 30 and the roller guide surfaces 14 reduces, rather forming a cause of aggravation of the vibration characteristic and short life. Therefore, the optimum amount of relief is such that the contact ellipse is within the width of the roller 30 at least during the application of a predetermined torque and no cutting-in occurs. To this end, the diameter  $d$  of the relief portions 15a and 15b is not less than the roller end surface diameter  $d_i$ .

The relief portions 15a and 15b, as seen in a cross section (Fig. 1), are formed by an arcuate curve which smoothly respectively connects both ends of the roller guide surfaces 14 to the minor and major inner diameter portions 16 and 18 of the outer joint member 10. In the embodiment shown by way of example in Fig. 1, the length of the contact ellipse shown in two-dot chain lines is equal to the distance between the points of connection between



the roller guide surfaces 14 and the relief portion 15a and 15b.

Sub Art> As has been described, in the first embodiment of the invention, the form of contact between the roller and the roller guide surfaces is circular contact and the contact ratio is set so that the widthwise contact ellipse length is not more than the widthwise length of the roller during the application of a predetermined torque, whereby weight reduction, compactification and good durability of the tripod joint can be achieved. Fig. 4 illustrates this. In the same figure, a conventional tripod joint is shown in the left half and the tripod joint embodying the invention is shown in the right half for comparison.

Further, the provision of relief portions in the roller guide surfaces eliminates the danger of the roller cutting into the roller guide surfaces when the tripod joint is rotating while taking an operating angle; thus, the vibration characteristics are improved and reduction of vibration of the tripod joint has been achieved.

Second embodiment of the present invention will now be described with reference to Figs. 6 and 7.

Sub Art> The first and second embodiments are the same as far

as the basic construction of tripod joint is concerned and as previously described in connection with Figs. 2A, 2B, 3A, 3B, and 3C. Here, the outer peripheral surface of the roller 30 may be a partial spherical surface with its center of curvature located on the axis; besides this, it may be a convexly curved surface using an arc as its generating line with its center of curvature located at a position radially spaced from the axis. The form of contact of the roller 30 with the roller guide surfaces 14 may be angular contact as shown in Fig. 5A or circular contact as shown in Fig. 5B. Angular contact has a certain contact angle and occurs at two points, so that contact ellipses occur at two points in the direction of contact angle. Circular contact occurs between spherical surfaces and at one point. In either case, it is necessary to set the width  $L_s$  of the roller 30 so that the contact ellipse does not deviate from the end surface of the roller 30 but comes within the roller width when a predetermined torque is applied. If the contact ratio is small, the contact ellipse becomes larger during torque application, exceeding the width  $L_s$  of the roller 30, leading to short life. Reversely, if the contact ratio is large, the contact ellipse becomes smaller, but the surface pressure increases, accelerating the wearing of the contact portions, leading to short life. Structurally, however, the surface pressure in the tripod joint is severest in the region between the



representing the calculated skew angle  $\theta_2$  (deg). It is seen from the same figure that the thrust force is at a minimum when the skew angle  $\theta_2$  is in the range of  $4.0^\circ - 4.5^\circ$ . When the skew angle  $\theta_2$  exceeds  $4.5^\circ$ , the thrust force increase until it saturates at a certain level. Further, skew angle  $\theta_2$  becomes smaller than  $4.0$ , the thrust force tends to increase. Therefore, concerning the skew of the needle rollers 32, setting the skew angle  $\theta_2$  in the range of  $4.0^\circ - 4.5^\circ$  makes it possible to reduce the induced thrust in the tripod joint and achieve reduction of vibration.

As described above, the tripod joint according to the second embodiment comprises an outer joint member having axially extending track grooves formed at three circumferentially equispaced positions in the inner periphery, a tripod member consisting of a trunnion barrel adapted to be fitted to a shaft for torque transmission and trunnion journals radially projecting from three circumferentially equispaced positions in the trunnion barrel, and rollers respectively attached to the trunnion journals for rotation through a plurality of needle rollers and received in the track grooves, each roller being guided at its outer peripheral surface by roller guide surfaces formed in opposite lateral walls of the track groove. Accordingly, it becomes possible to reduce vibration in a

tripod joint by controlling the skew angle of the needle rollers so that it is within a predetermined specified value.

Since the smaller of the two types of skew angles, the skew angle ( $\theta 1$ ) which can occur due to the circumferential clearance and the skew angle ( $\theta 2$ ) which can occur due to the radial clearance, is the skew angle which can actually occur, measures against skewing of needle rollers can be taken by controlling only the latter skew angle ( $\theta 2$ ), by ensuring that the skew angle ( $\theta 1$ ) of the needle rollers which can be produced by the circumferential clearances is larger than the skew angle ( $\theta 2$ ) of the needle rollers which can be produced by the radial clearances in an annular space between the roller and the trunnion journal ( $\theta 1 > \theta 2$ ).

Third embodiment of the invention will now be described with reference to Figs. 8A, 8B, 9A, and 9B.

The first, second, and third embodiments are the same as far as the basic construction of tripod joint is concerned and as previously described in connection with Figs. 2A, 2B, 3A, 3B, and 3C. Here, the root of the trunnion journal 22, as shown in Fig. 8A, is of two-step shape. That is, a step portion rising from the trunnion barrel 21 is formed and a cylindrical outer peripheral

surface 24 extends from the step portion. The corner at the base end of the cylindrical outer peripheral surface 24 is one continuous R surface having a predetermined radius of curvature Rb. In the case of prior art shown in Fig. 8B, the trunnion barrel 21' directly connects to the cylindrical outer peripheral surface 24' through an R surface having a radius of curvature Ra. As is apparent from a comparison between the two figures, there are relations  $R_a > R_b$  and  $tw_1 > tw_2$ .

Table 1 shows examples with reconsideration given to the dimensional proportions of various portions in the embodiment shown in Figs. 2A and 2B.

[TABLE 1]

ITEM	RECONSIDERATION OF PROPORTIONS (%)		EFFECTS RESULTING FROM RECONSIDERATION			
	Prior art	Examples	a	b	c	D
$\Phi ds/PCD$	45 - 49	50 - 55	○	○	-	-
$\Phi dr/SDj$	60 - 63	65 - 70	-	○	○	-
$\phi D2/\phi D1$	59 - 64	66 - 72	-	-	○	○
$Ls/\phi Ds$	32 - 36	24 - 27	○	○	-	-
$\Phi Dj/\phi Ds$	46 - 57	54 - 57	-	○	-	-
$\Phi Dj/\phi ds$	73 - 86	83 - 86	-	○	-	-
$Ln/\phi Dj$	58 - 76	47 - 50	○	○	-	-

In the examples shown in Table 1, the dimensions of the various portions (see Figs. 9A and 9B) in the arrangement of Figs. 2A and 2B were set as follows.



The proportion 100 ( $L_s / \phi D_s$ ) of width/outer diameter of the roller 30 was set to 24% - 27%. The width  $L_s$  and outer diameter  $\phi D_s$  of the roller 30 were set to optimum values by considering the contact ellipse length and contact surface pressure between the roller 30 and the roller guide surface 14 when a predetermined torque was applied.

The proportion 100 ( $\phi D_j / \phi D_s$ ) of trunnion journal diameter/roller outer diameter was set to 54% - 57%. The trunnion journal diameter  $\phi D_j$  was made equal to the current dimension in order to secure torsional strength, and the roller outer diameter  $\phi D_s$  was set on the basis of the contact surface pressure.

The proportion 100 ( $\phi D_j / \phi d_s$ ) of trunnion journal diameter/shaft diameter was set to 83% - 86%. It was set to the same dimension as the current proportion in order to secure torsional strength and durability.

The proportion 100 ( $L_n / \phi D_j$ ) of needle roller length/trunnion journal diameter was set to 47% - 50%. The needle roller length  $L_n$  was set by considering the maximum contact surface pressure for the bearing. In addition, by reducing the size of the root R of the trunnion journal 22





between the needle rollers and the trunnion journal, and this surface pressure is allowed up to a predetermined value, whereby a radically compact design of an outer joint member has been achieved.

In the aspect of durability, notice is taken of contact surface pressure in the trunnion journal and the contact surface pressure in the trunnion journal is allowed up to about 1.15 times as large as the usual value (see Table 2), as compared with the conventional tripod joint. Since the conventional tripod joint has not less than twice the durability of the DOJ (double offset joint), the tripod joint according to the third embodiment of the present invention should have durability equal to or greater than that of the DOJ.

[Table 2]

	Elliptic leg axis	True circle leg axis
Prior art	259.2	343.7
Examples	292.9	398.1
Proportion	1.13	1.16

Unit: kgf/mm<sup>2</sup>